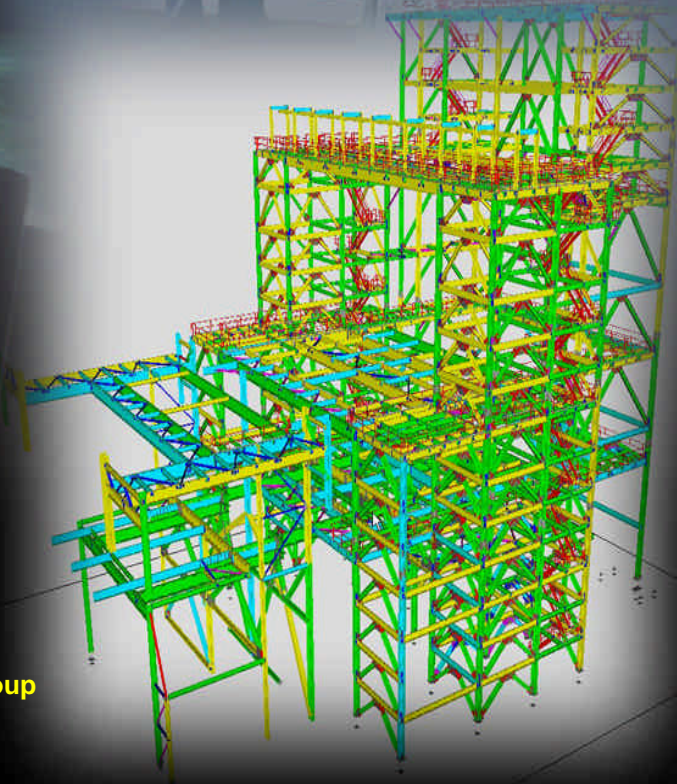
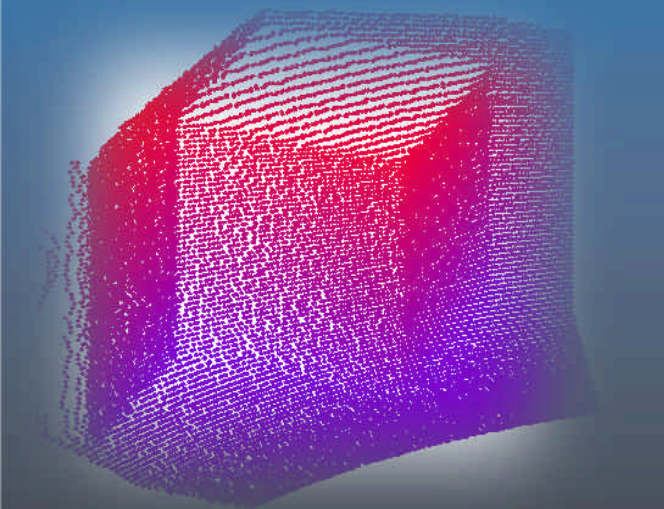


The Automated Construction Site: Data Exchange Problems

NIST

May 29, 2003



Dr. William C. Stone
Leader
Construction Metrology & Automation Group
CONSIAT Program Manager

Average Job Labor Cost

- 1% Material and Component Tracking
- 1-2% Re-work
- 1-3% "As-built" Is "as-is" = "should-be"
- Workers today are less productive than 70 years ago

**US
CONSTRUCTION:
9-13% GDP**

Cost to the Industry: $(3 \text{ to } 6\%)*(13\%)*(GDP) \approx \$35-70(10)^9$

**Time is the Issue:
Get it done Right
the First Time,
On Time**





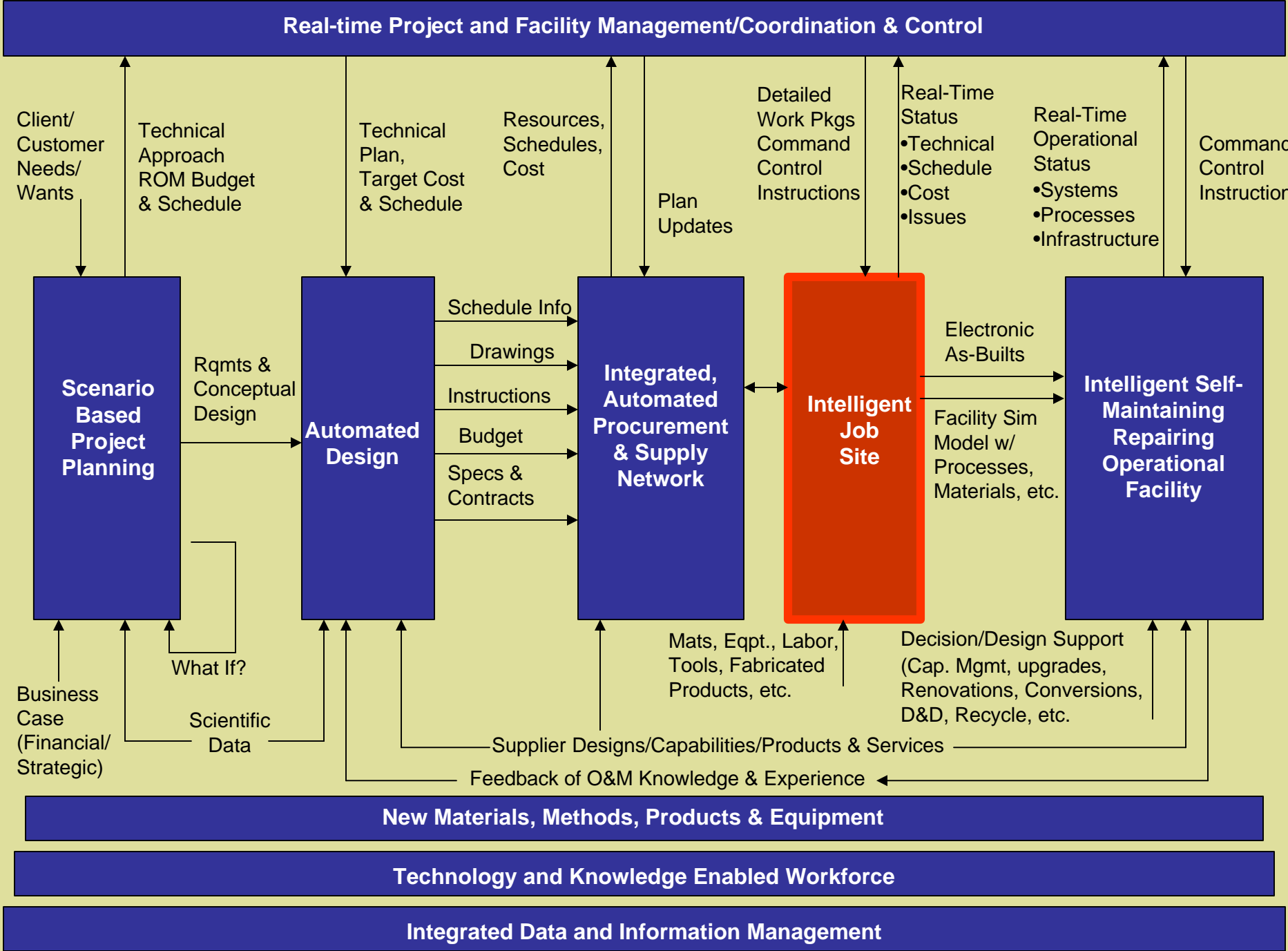
The Second Case for Automation: Safety

- Incidents of occupational injury for construction workers – 10% of all cases
- Worker's compensation insurance for steelworkers is 19.3% of wages
- Percentage of fatalities in construction industry (building erection) from falling is 43%



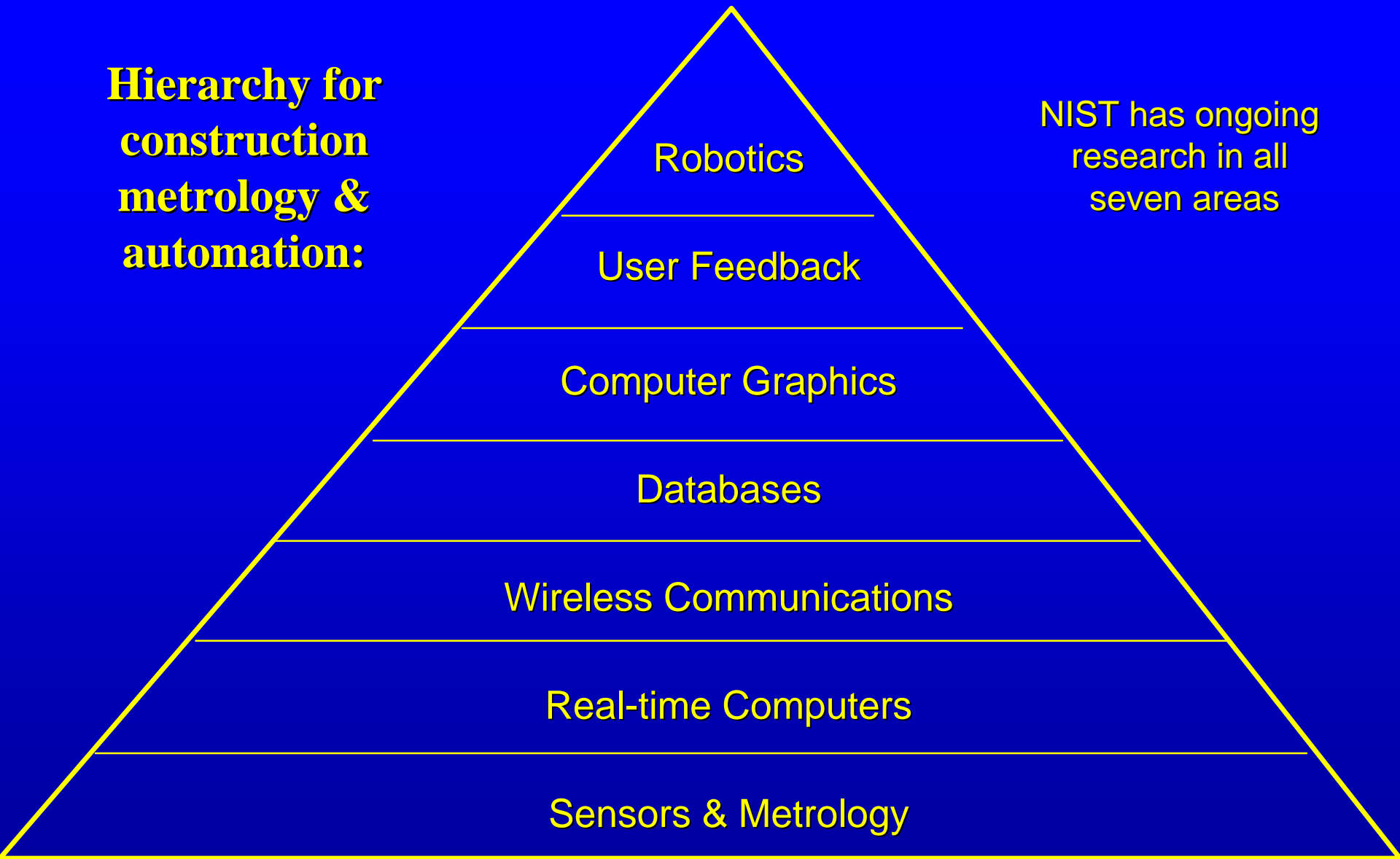
.J. Ricles, PhD "Next Generation Steel Structures"

.Talk given at Automated Steel Construction Workshop, NIST, June 2002



**Hierarchy for
construction
metrology &
automation:**

NIST has ongoing
research in all
seven areas



Robot Positioning

- Encoder
- ArcSecond

? LADAR ←

? GPS

? Ultra-Sonic ←

Object Recognition

- CompTrak

? LADAR

? Machine Vision

? Ultra...

Robot Control

- ATR "RCS"
- Path Planner

Visualization

- VRML
- JAVA

? CORBA

Investigate

• 4D CAD

• SDK Z + F

• ArcSecond Tests

• CIS / 2

• *NIX Based Controller
- Current RCS Arch

• RCS Data Collection

• Sensor Fusion

Data Management

- Scheduling (Truck Loading)
- Material tracking
- 4D integration
- * - data exchange protocols/format

**Construction Automation REQUIRES Process Integration
... and therefore seamless SENSOR integration**

Total Station



GPS/Pseudolite



Site Spatial Measurement: Today and Tomorrow

Emerging Technologies



Fanning Laser



Non-Line-of-Sight Metrology

Some Measurement Sensors/Instruments in Construction

Surveying Instruments

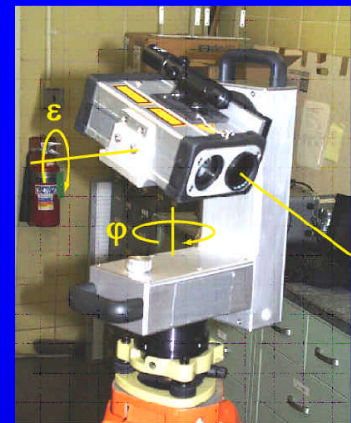
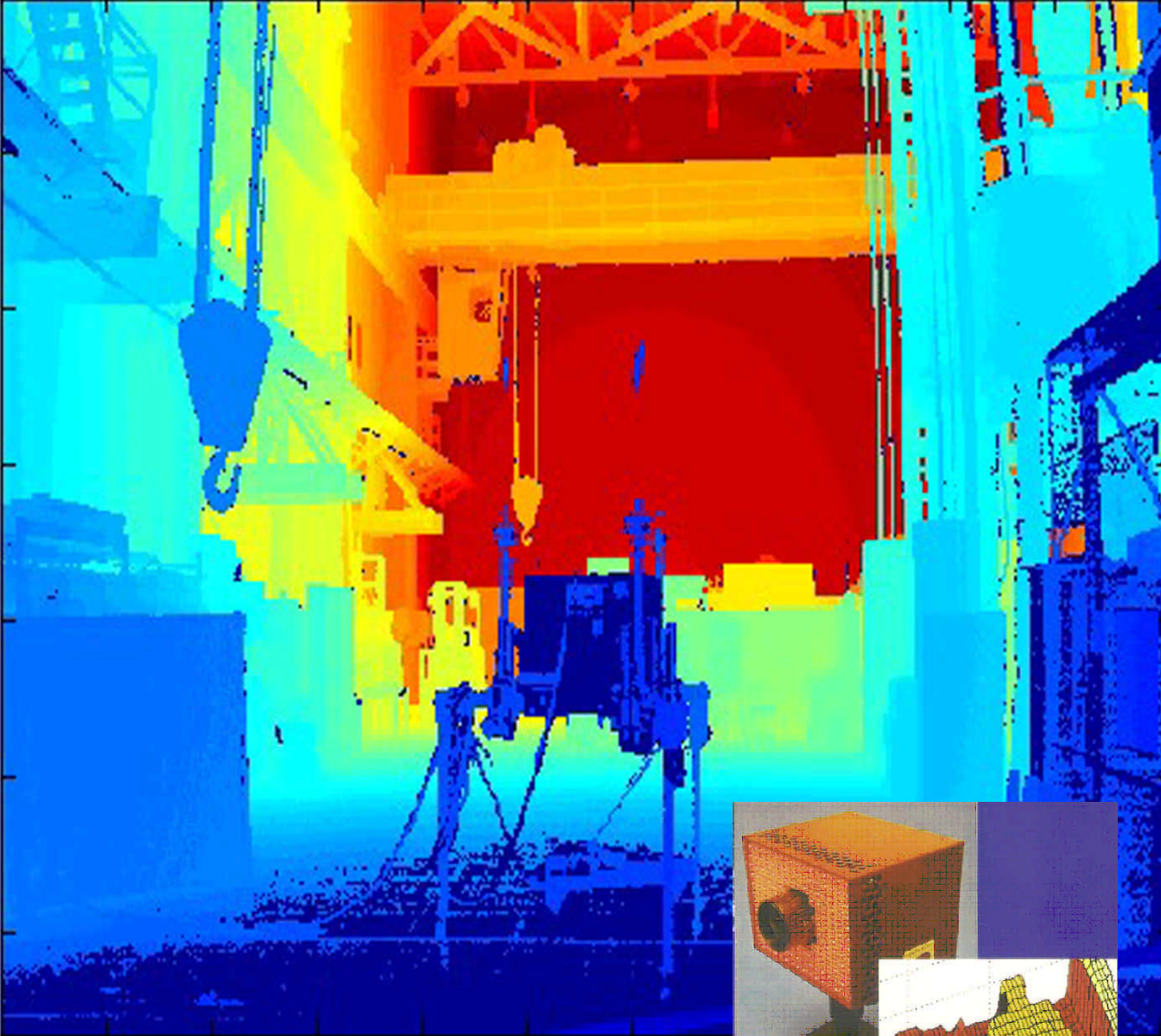
- Automatic Compensator Levels
- Digital Levels
- Laser Levels
- Digital Theodolites
- Digital Theodolites EDM's
- Total Stations
- Pulsed Laser Plummets
- Global Positioning System (GPS)
 - Code
 - Differential
 - Phase Differential / RTK
 - Pseudolites

Coordinate Measuring Lasers

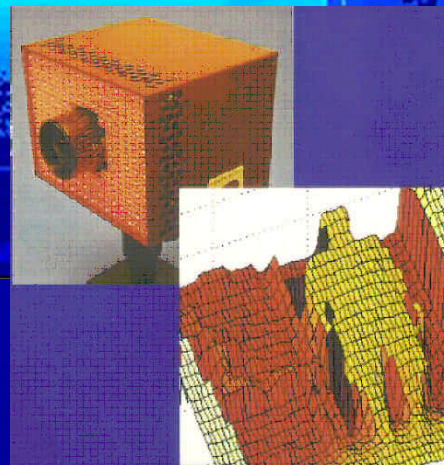
- Fanning Lasers
- Pulsed laser rangars using LIDAR (Light Detection and Ranging)
- Continuous wave laser rangars
- Laser Trackers
- LADAR (Laser Radar)

State Sensors

- Accelerometers
- Temperature Sensors
- Humidity Sensors
- Pressure Sensors
- Proximity Sensors
 - (e.g., ultrasound, capacitance, etc.)
- Encoders (angular & linear)
- Displacement Sensors
- Force Sensors
- Torque Sensors
- Strain Sensors
- Velocity Sensors



**1: The LADARS
are Coming...**



Construction Metrology & Automation Group

LADAR Information Content



**COLOR
CODED
RANGE
& LOCATION
“Range
Image”**

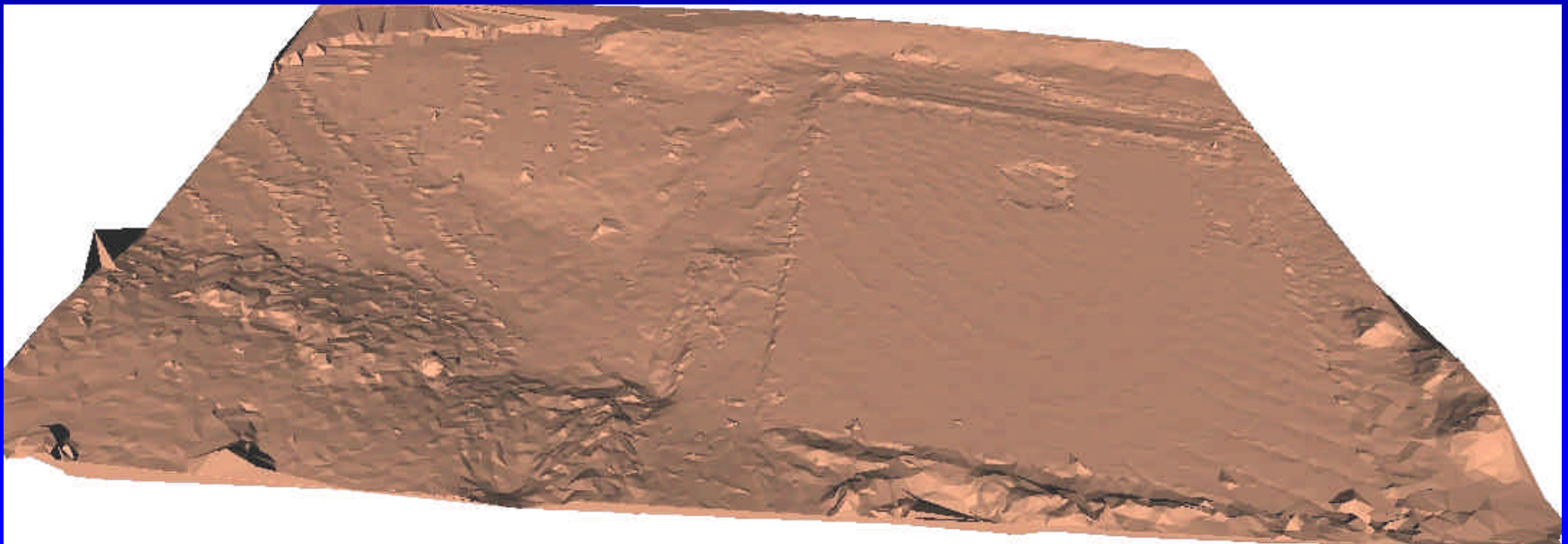


**B&W
RETURN
INTENSITY**

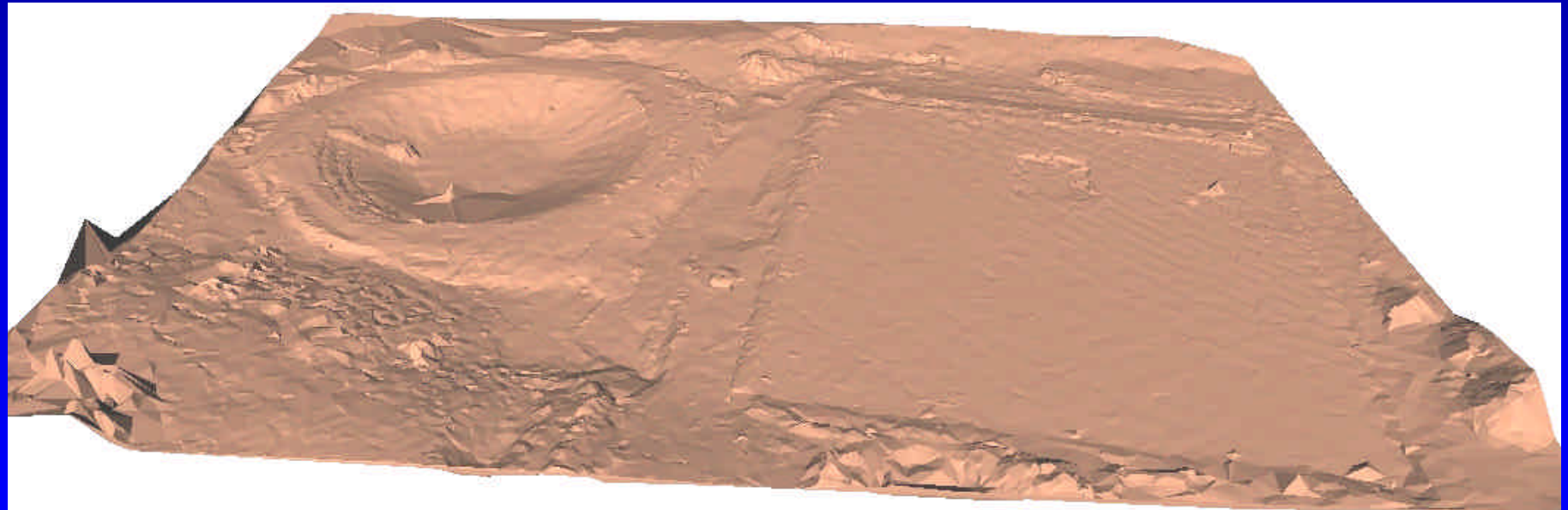


**DIGITAL
COLOR**

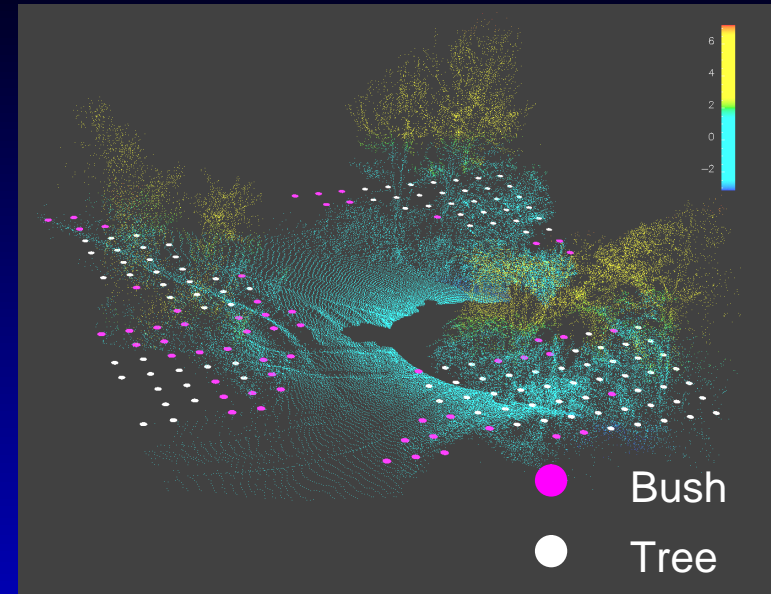
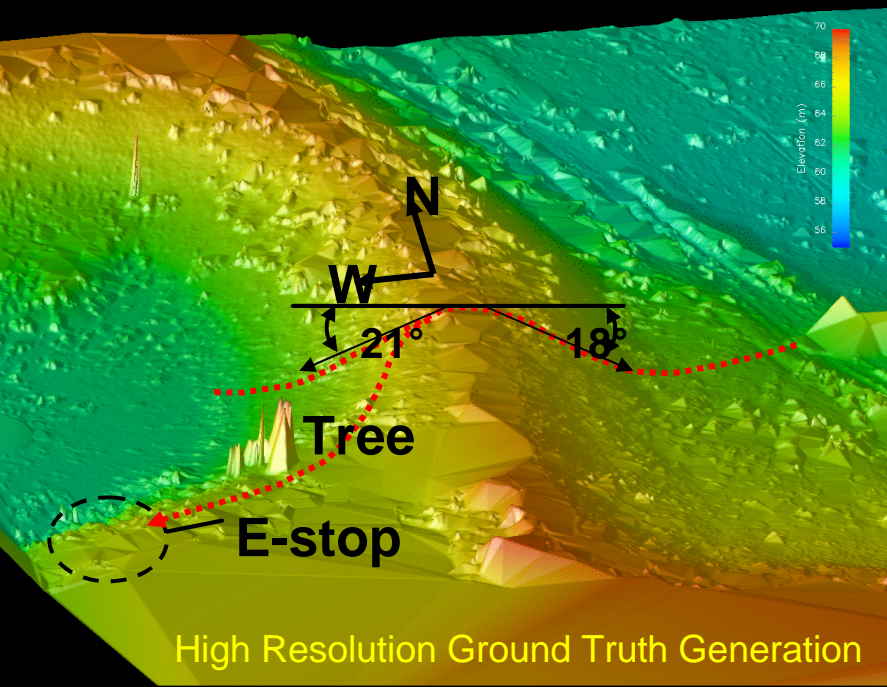




March 7, 2000

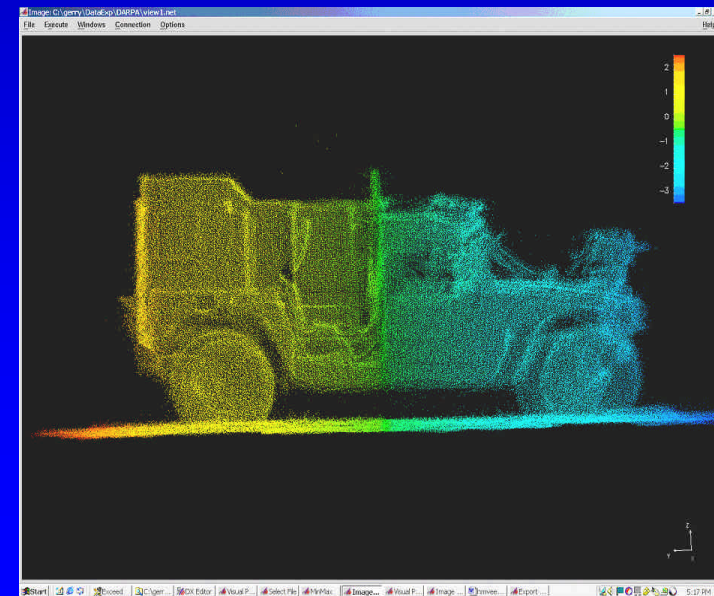
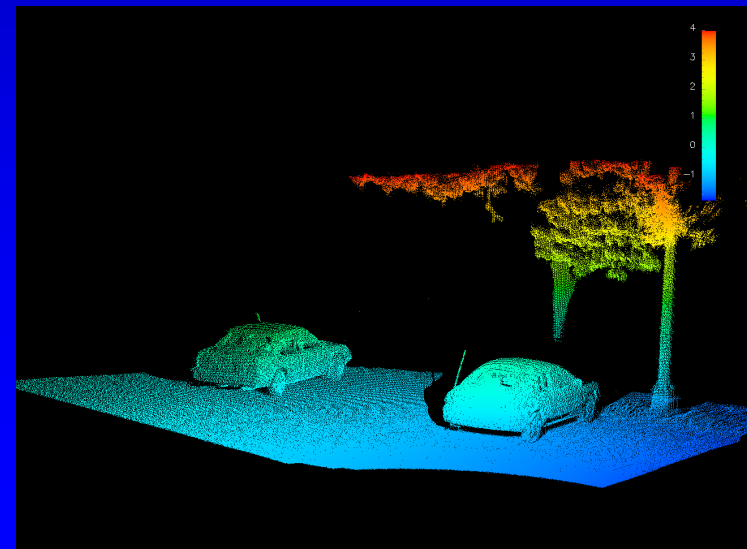


March 9, 2000



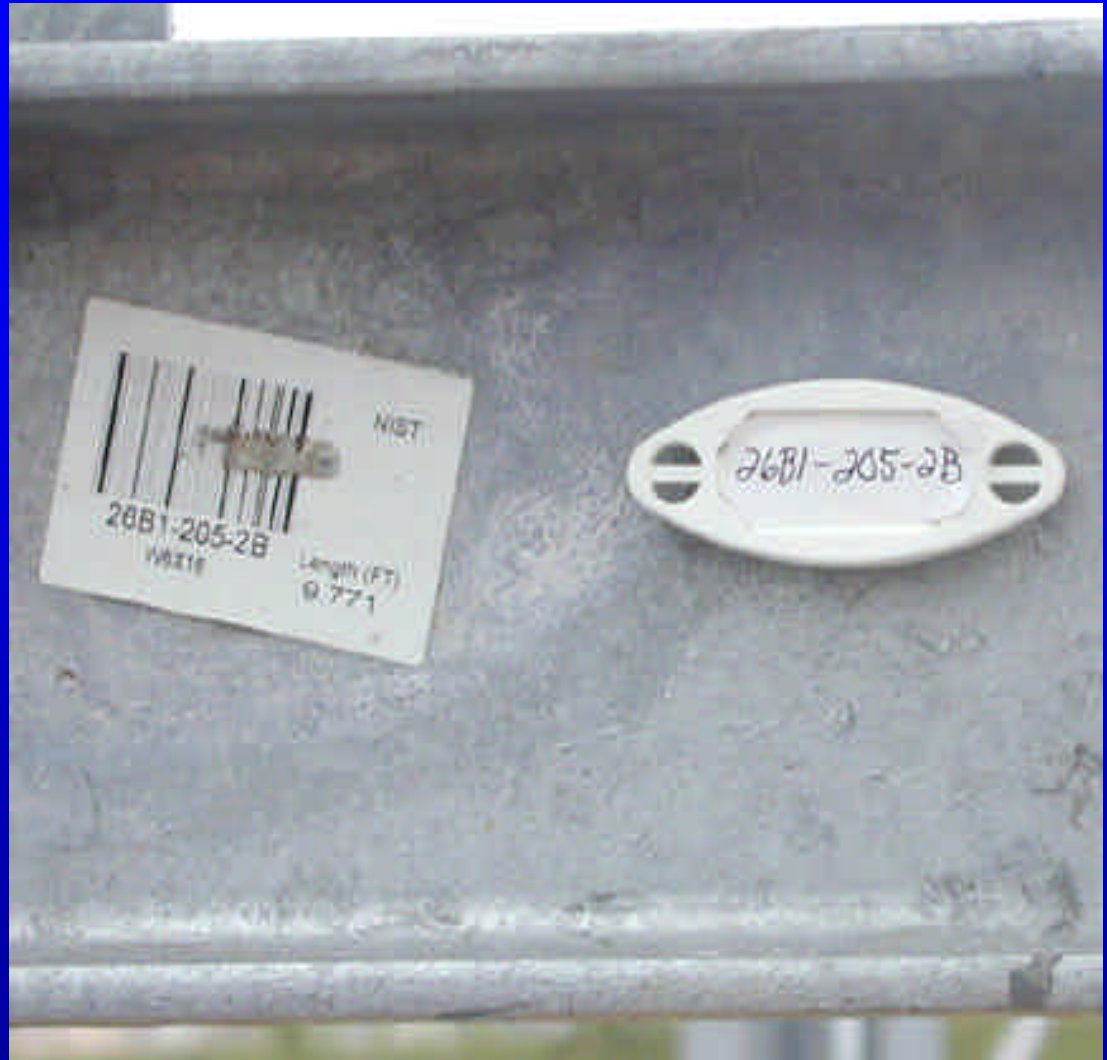
Real-time Derivative Quantity Analyses –
e.g. Terrain Traversability

Advanced LADAR applications



2: Self-Identification is Coming:

Bar Codes, RFID Tags,
Smart Chips, Long-
Range Auto Ident



Comp-TRAK

**AutoID
Laser Positioning
Wireless DB
Access**

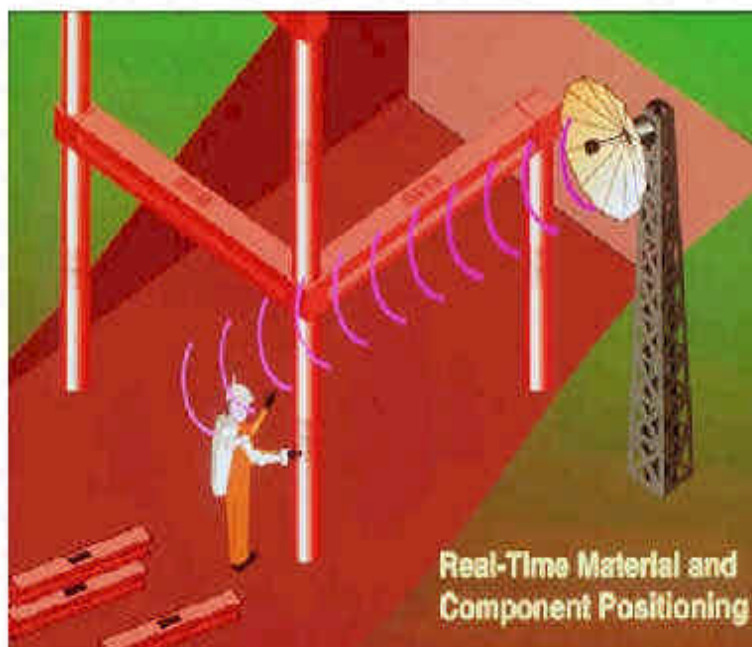


Comp-TRAK System



- Part ID via bar code
- Pose using Vulcan 3-D CMS
- Portable field computing
- Interactive web interfaces
- Project database
- Wireless communications
- Remote computing
- 3-D visualization

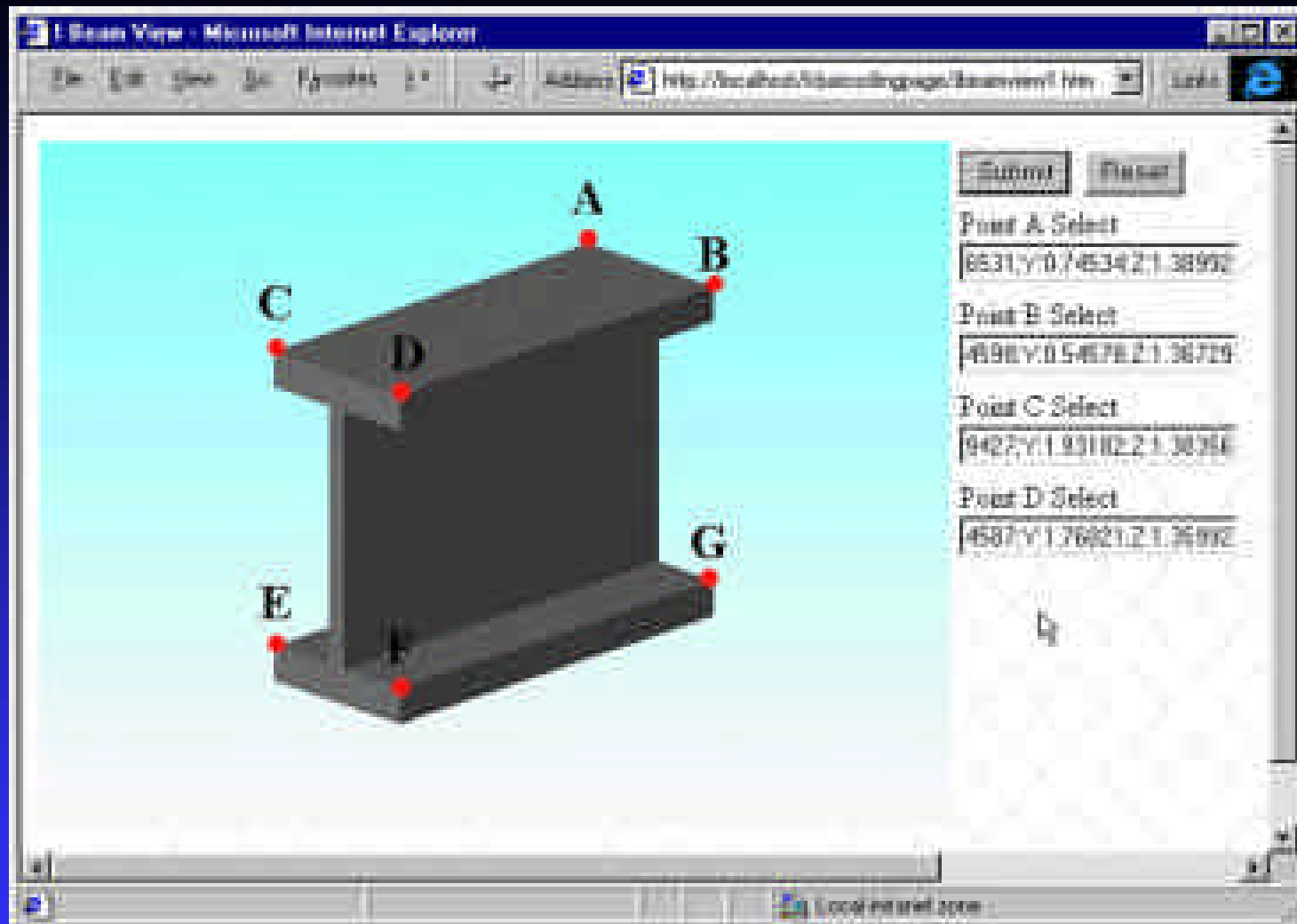
Welcome to the NIST Construction Component Tracking Website



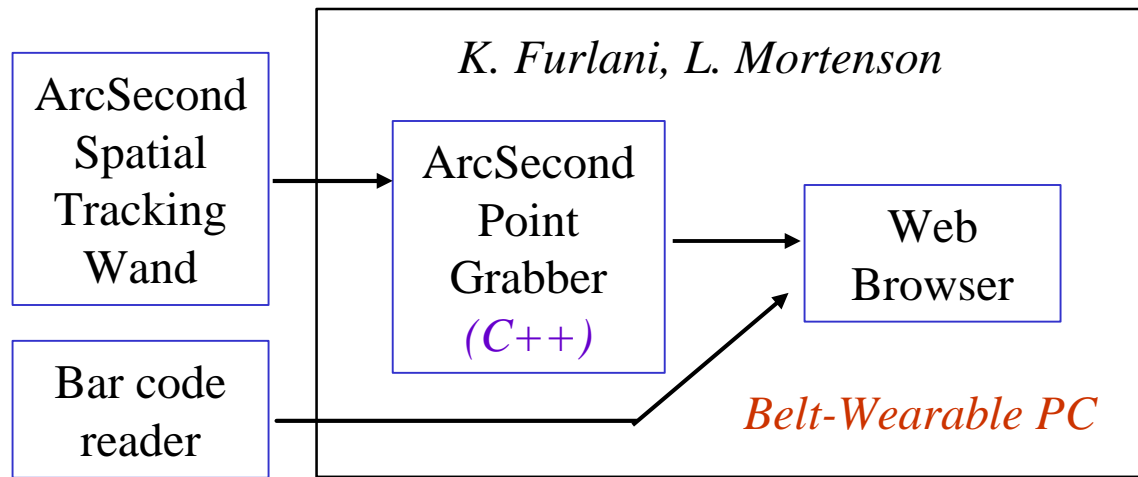
To access and register
information related to your
component:

Go to

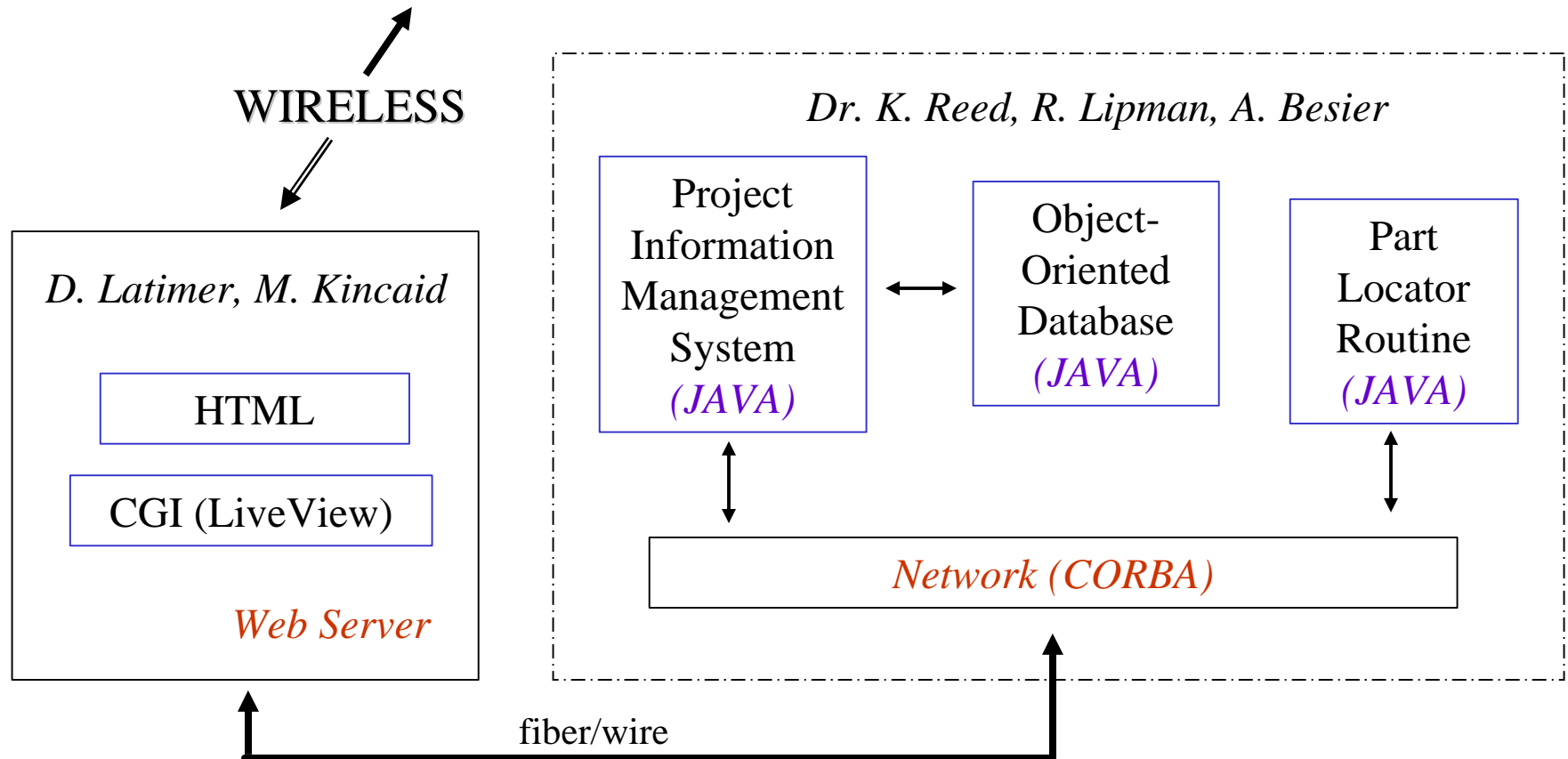
Bar Code Entry
or
RFID tag Entry



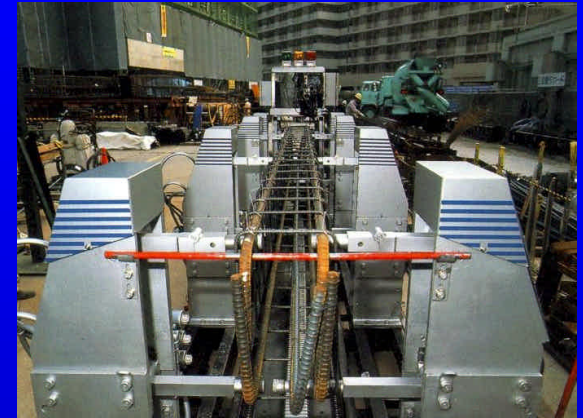
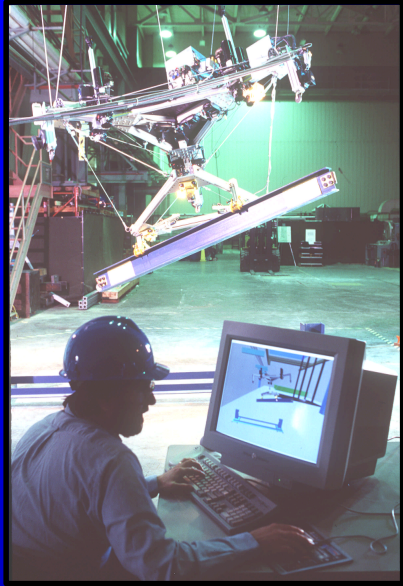
The 3D model provides visual queues for the location of key fiducial points necessary for component location and orientation acquisition.



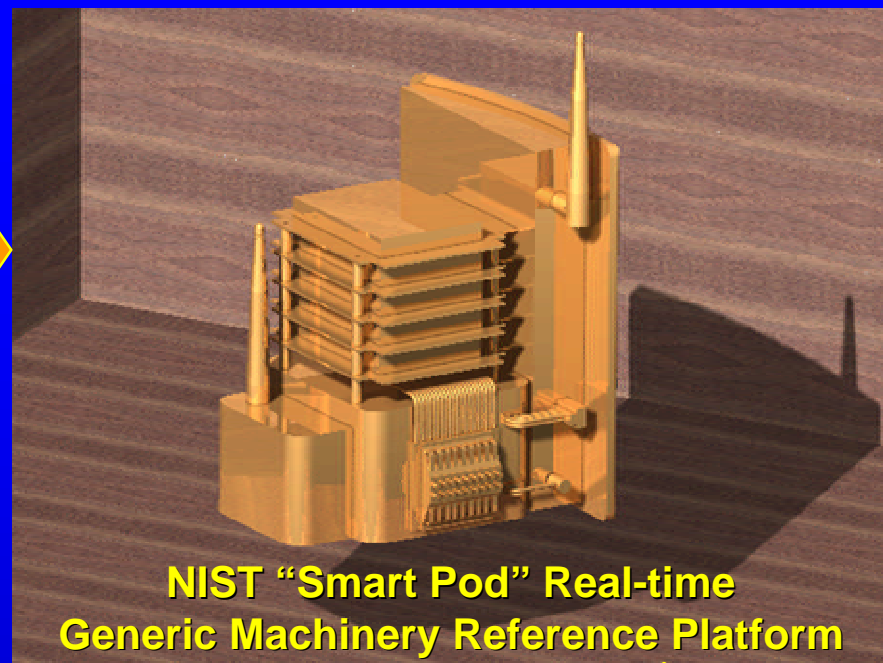
compTRAK **2001 System** **Architecture for** **Steel Tracking**



3: The Robots are Coming...



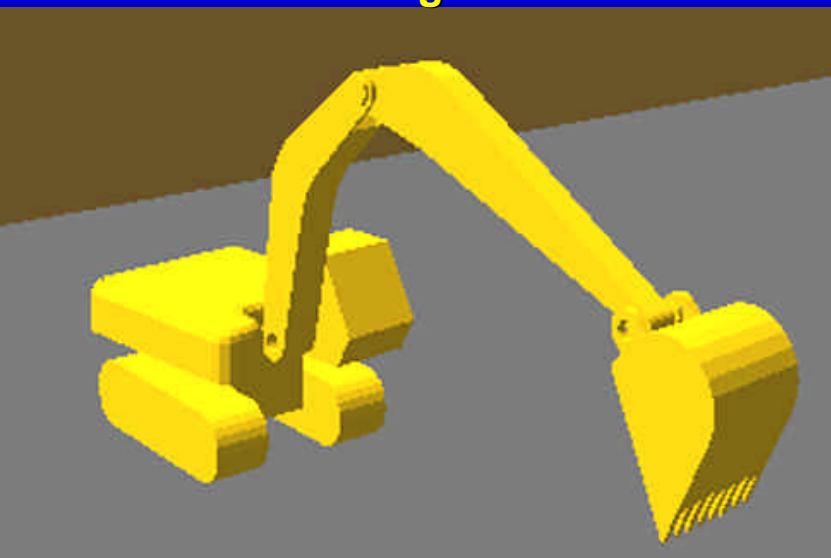
Jobsite Machines & Metrology Systems



**NIST "Smart Pod" Real-time
Generic Machinery Reference Platform**



Construction Management Simulator



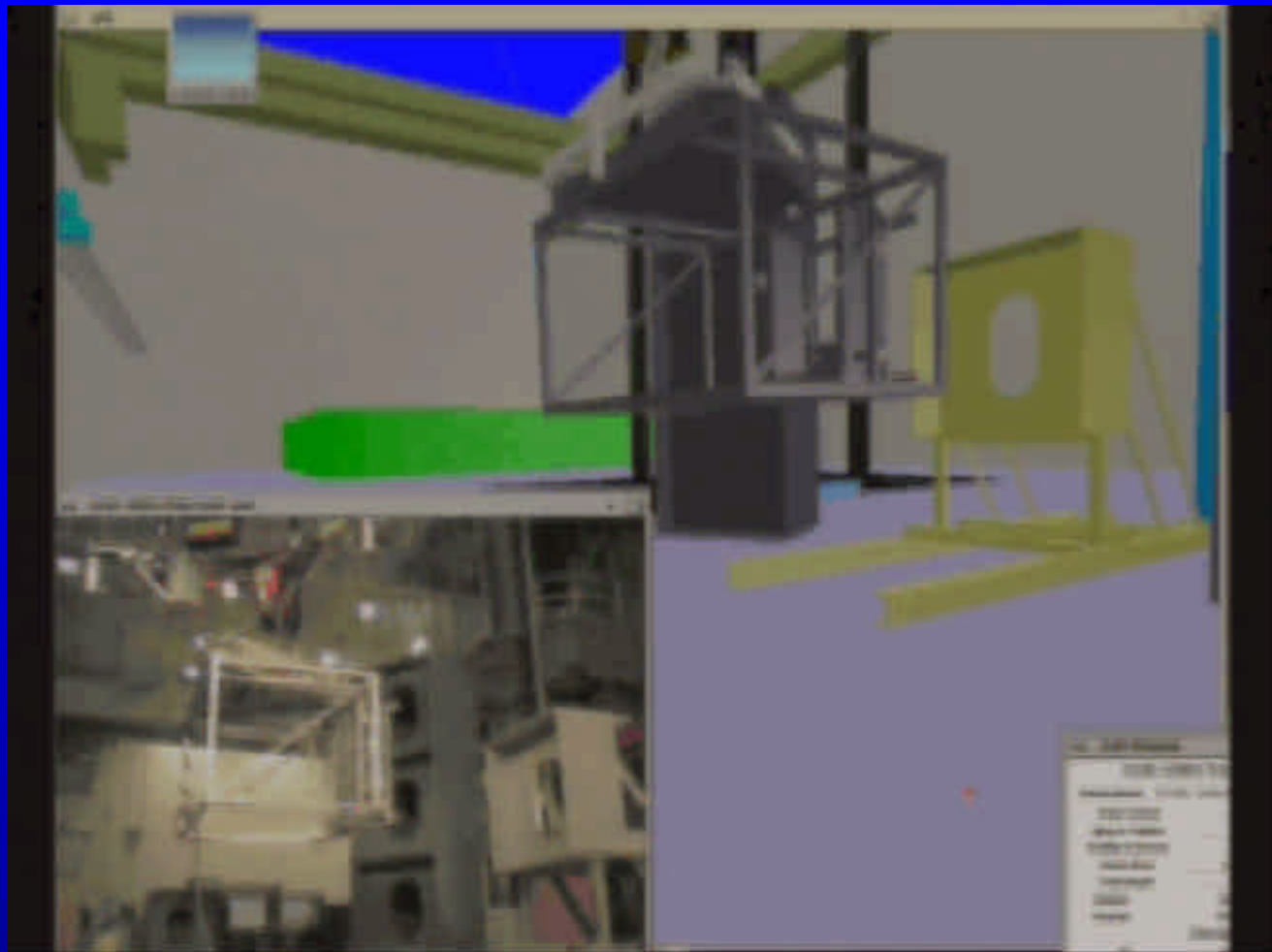
**Dynamic
Data-
Base**

**HIGH
SPEED
DATA
LINK
(ATM)**

**JOBSITE
WIRELESS
DATA
UPLINK
PACKET
STANDARD**

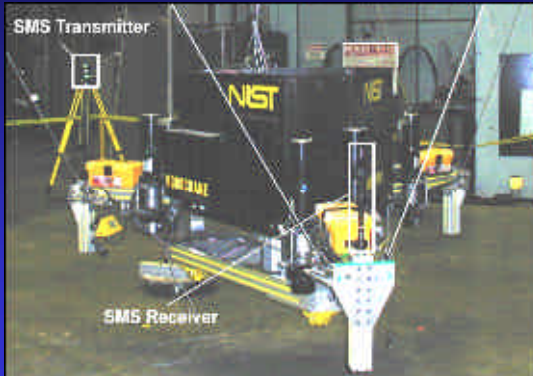
Construction Machine Tracking System

Early Success: Tele-op Control with Augmented Simulation 3D Interface

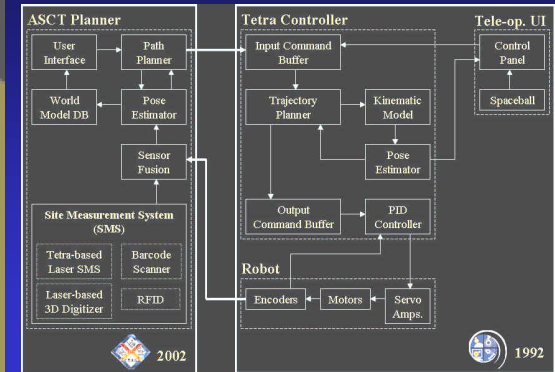


NIST Automated Steel Construction Project FY02 Major Accomplishments

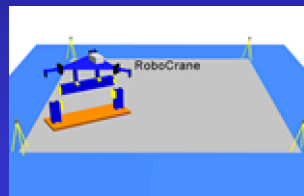
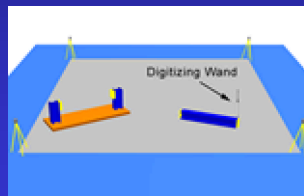
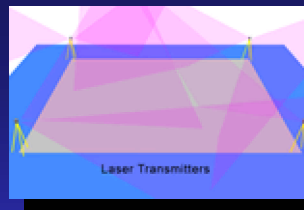
Applied new laser-sensors for 3D
robot pose estimation



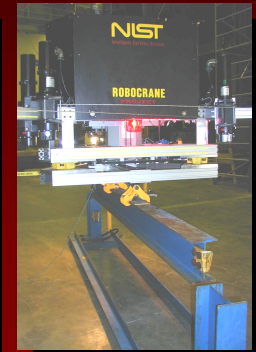
Developed new software
controller



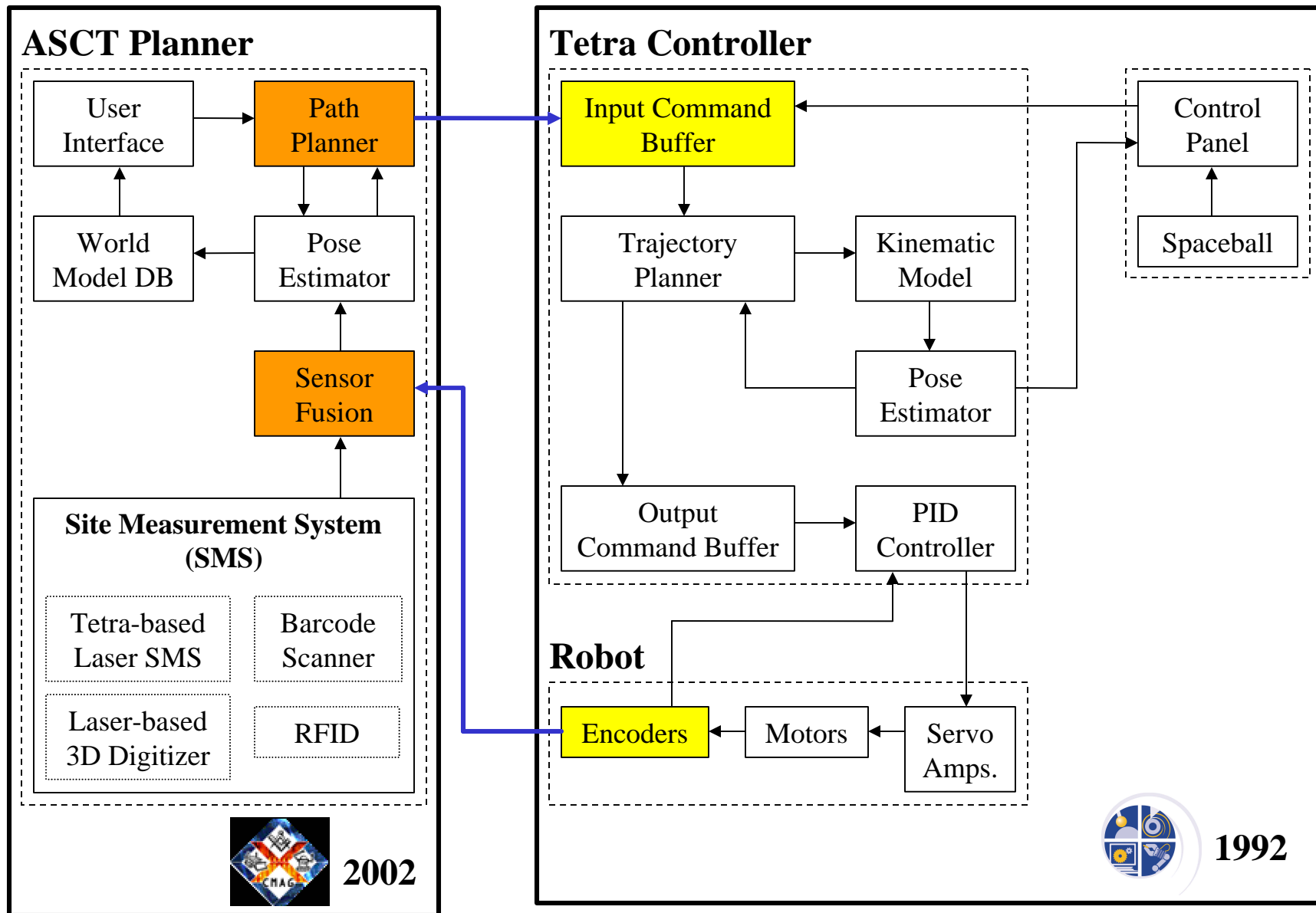
Developed new
visualization
tools



Demonstrated
AUTONOMOUS 6-DOF
Beam Pick-and-place



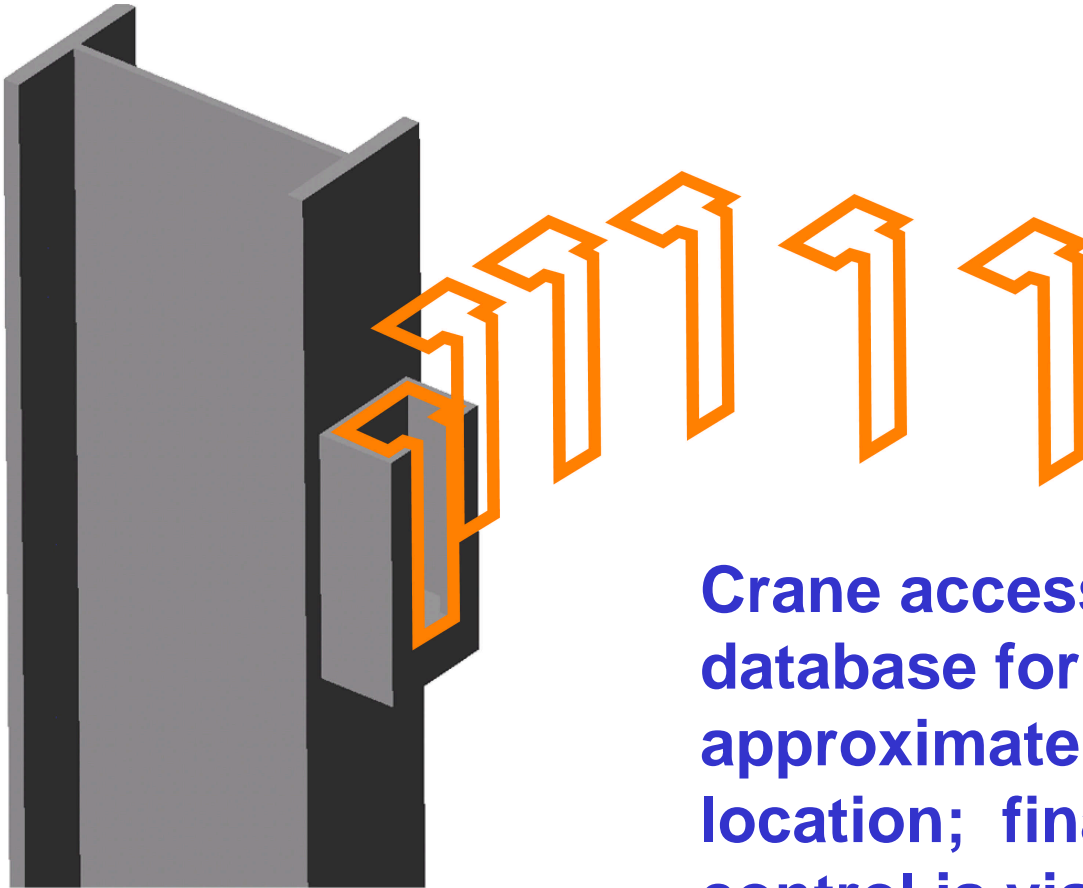
CONTROLLER



1992



LADAR-machine vision fusion for auto-docking trajectory generation



Crane accesses 4D site database for sequencing and approximate “seed” target location; final placement control is via real-time sensor lock.



Solving the Auto Placement Problem: learning from Autonomous Mobility



HMMWV



XUV

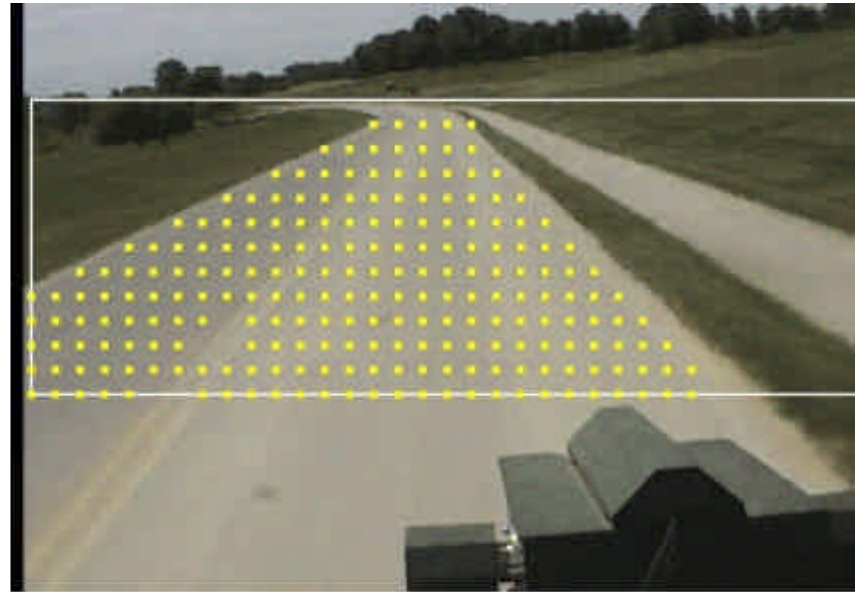


Real-time Road following

Edged-based



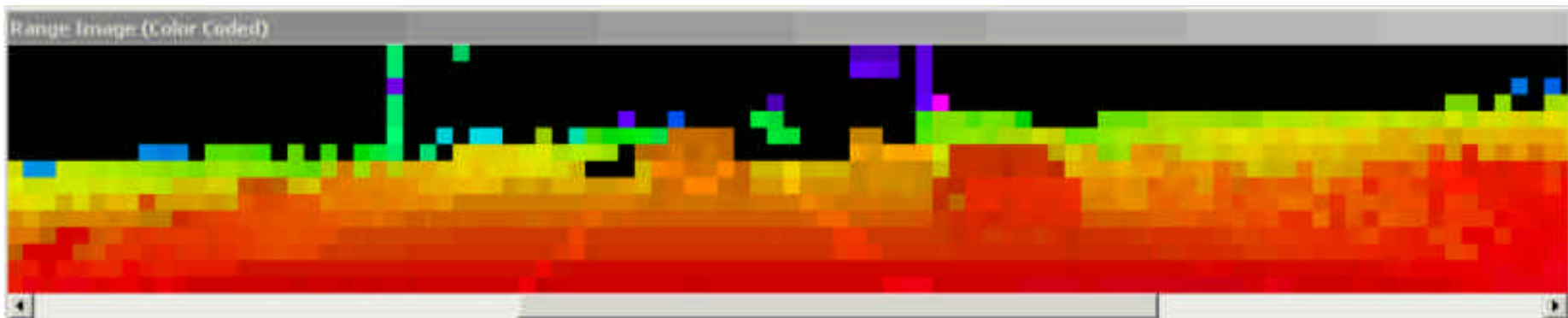
Region-based



Machine Vision Based Guidance: Presently limited to effective use on quasi-2D problems. Solution: fuse with real-time LADAR data



Present Real-time State-of-Art for polygon scanning LADARs (10 Hz x 128 x 32 pixel)



Present Real-time State-of-Art for FPA LADARs (30 Hz+ x 32 x 32 pixel)

FIATECH Information Technology Infrastructure Construction Job of the Future

Machinery Status

GPS Position
GPS Attitude
IMU, laser, Aiding Sensors

Machine

Real-time Machine Characterization, Calibration, & Control Services & Standards

LRCN

Wireless Node

T

CONSTRUCTION SITE

Component Tracking

QC Officer

LRCN

T

Net Switch

High Speed Net

Video & Audio Input

Video & Audio Output

T

Video 1

T

Video 'n'

T

Mike

T

Speaker

T

Helmet Mounted & Headup Displays

Amorphous Scanning & Object Recognition

Robotic Scanner

LRCN

T

Lidar Scanner

Lidar Coordinates

Wireless Interoperability Standards for Construction Data Transfer

Wireless Interoperability Standards for Human Interface

LRCN = Local Real-Time Computational Node
T = Wireless Telemetry Node

Opportunities for NIST (standards)

3D Chronological / Dynamic Project Database

Earthmoving Simulation and
tracking; object recognition,
collision detection

Component Tracking, work
package scheduling, vendor
and laborer payment (auto)

Machinery Tracking, Simulation,
Control, and Maintenance

Ethernet
Switch

Net
Switch

Interoperability
Standard
for ubiquitous
autonomous
and semi-autonomous
agent
coordination

CONSTRUCTION MANAGEMENT

Video
&
Audio
Input

Video 1

Video 'n'

Mike

Video
&
Audio
Output

Speaker

Office
Projection
Screen

Opportunities
for NIST
(standards)

Pipe Spool & Steel frame
fabrication (auto programming
and sequencing for production)

Part ID (barcode or RFID)
and loading sequence for
site delivery

STEP
part
AP's

RFID
Interoperability
Protocols

Ethernet
Switch

Net
Switch

FABRICATOR

Production status, raw mat.
ordering, transport mgt.

Video
&
Audio
Input

Video 1

Video 'n'

Mike

Video
&
Audio
Output

Speaker

Office
Projection
Screen

Opportunities
for NIST /Industry
Collaborations &
Demonstration
Projects

Large-Scale CMM



LADAR



Augmented Sims: 3DVRML

